

Guest Comment: Why undergraduates leave the sciences

Our recent report, "Talking about Leaving," is the culmination of a three-year study whose overall aim was to discover, and to establish the relative importance of, factors bearing upon the decisions of undergraduates at four-year colleges and universities to switch from science, mathematics, and engineering majors into disciplines which are not science based. The work contributes to the ongoing national debate about the quality of science, mathematics, and engineering (SME) undergraduate education, and seeks to explain net losses from science to nonscience majors, which range from 38% in engineering, 51% for both the physical and biological sciences, to 63% in mathematics. Concern about this apparent "wastage" of talent is enhanced, both because these losses occur among the most highly qualified of college entrants, and because they are disproportionately greater among women (including women of high demonstrated ability) and students of color, despite a serious national effort to improve their recruitment and retention.

Faculty have traditionally explained undergraduate departures as "appropriate"—either as a benign cull of students who are underprepared, less able, less interested, or less willing to work hard, or as an entirely laudable decision following discovery (after several semesters in science and mathematics) that their true vocation lies elsewhere. However, neither these, nor any other assumptions about the nature of the undergraduate science, mathematics, or engineering experience had ever been systematically explored.

We therefore began an inquiry on seven different campuses, chosen to represent those four-year institutions which most SME undergraduates attend. Validation of findings was carried out further at six additional institutions. We interviewed a broadly equal number of students declaring (or intending to declare) SME majors who had switched into non-SME majors, and of graduating SME seniors in a total sample of 460 students. Samples were drawn in collaboration with participating institutions, were subdivided by gender and ethnicity, and included only students who, on the basis of their mathematics Scholastic Aptitude Test (SAT) scores (a minimum of 650), appeared to be capable of handling the course work. Approximately 75% of the data were gathered by hour-long personal interviews, and the balance in small focus groups, yielding approximately 600 tape-recorded and transcribed interview hours.

We discovered, somewhat to our surprise, that the same set of problems led both to switching, and to serious discontent among "persisters" with their educational experience. We did not find switchers and nonswitchers to be two different kinds of people: they did not differ by attributes of measured ability or moral character, to any degree that was sufficient to explain why one group left, and the other group stayed. Rather, we found an array of abilities, motivations, and study-related behaviors across the entire sample. The most common reasons for switching arose from a set of twenty-three concerns which, to varying degrees, were shared by switchers and nonswitchers alike. Exactly the same kinds of reservations about their majors prompted some undergraduates to switch majors, or created problems for a high proportion of others, whether they left or stayed. What distinguished the survivors from those who left was their development of particular attitudes or coping strategies—both legitimate and illegitimate. Serendipity also played a part in persistence, often in the form of intervention

by faculty at a crisis point in the student's academic or personal life. On every campus, we also found a small group of SME seniors (16.5%) who were planning to leave their disciplines for non-SME careers following graduation.

Again, to our surprise, we found no major differences between institutions of different types in the nature or frequency of problems raised by their SME students. Though there were some variations in the ranking of problems by institutional type, there was little differentiation across all seven campuses in identification of the most serious concerns by either switchers or nonswitchers. Every category of problem was found on every campus, regardless of differences in size, mission, funding, selectivity, or reputation. We also found strong support for the hypothesis that a high proportion of the factors cited as significant in switching decisions arise either from structural and cultural sources within institutions, or from students' concerns about their career prospects.

There was a strong similarity between switchers and non-switchers in almost half of the issues they described: the four most commonly cited concerns leading to switching decisions were also cited as concerns by between 31% and 74% of nonswitchers. Ranked according to their contribution to switching decisions, they are: lack or loss of interest in science; belief that a non-SME major holds more interest, or offers a better education; poor teaching by SME faculty; feeling overwhelmed by the pace and load of curriculum demands.

Seven issues were cited as shared concerns by more than one-third of both switchers overall, and of nonswitchers. They include the four listed above, plus (in rank order): choosing an SME major for reasons that prove inappropriate; inadequate advising or counselling about academic, career, or personal concerns; and insufficient high school preparation (in content, conceptual grasp, or study skills). An additional four concerns were shared by a smaller proportion (20–30 %) of all switchers and nonswitchers: the financial problems involved in completing SME majors; conceptual difficulties with one or more SME subject(s); the unexpected length (i.e., more than four years) of SME majors; and language difficulties with foreign faculty or teaching assistants.

Only four of the issues cited as contributing to switching decisions were *not* substantially shared with nonswitchers. Of this group of issues, three reflect underlying concerns about career prospects: that the perceived job options, or material rewards, of SME careers were not worth the effort involved in getting an SME degree; that the perceived job satisfactions and/or lifestyle associated with SME careers were unappealing; and that careers in non-SME fields were more appealing. The fourth issue reflects the experience of low grades and of curve grading in the first two years, leading to discouragement and loss of confidence in the ability to do mathematics and science.

All of the most commonly mentioned problems of both switchers and nonswitchers imply criticisms of the structure of SME learning experiences, and of the practices and attitudes which sustain them. The economic problems raised by switchers, and to a lesser degree by nonswitchers, reflect a shared level of anxiety about career and lifestyle prospects at a time of economic uncertainty, and about the level of satisfaction that careers open to those with SME qualifications

are likely to offer. Anxieties about future career and lifestyle prospects, voiced by both switchers and nonswitchers, increased over the three years of interviewing.

Criticisms of faculty pedagogy contributed to one-third (36.1%) of all switching decisions and were the third most commonly mentioned factor in such decisions. However, complaints about poor teaching were cited as a near-universal concern by switchers overall (90.2%), and were the most commonly cited complaints of nonswitchers (73.7%). Complaints about faculty pedagogy cannot, however, be seen in isolation. All four of the most highly ranked factors contributing to switching decisions relate to some aspect of poor teaching: in one way or another, concerns about pedagogical effectiveness, assessment practices, and curriculum structure, pervade all but seven of the twenty-three issues. For example, although the following concerns were counted separately from those directly citing "poor teaching," they clearly bear upon pedagogical efficiency:

- (i) SME faculty are often seen as "unapproachable" or unavailable for help with academic or career-planning concerns.
- (ii) The rejection of SME careers or lifestyles is partly a rejection of SME faculty and graduate students as role models.
- (iii) The curve-grading systems widely employed by SME faculty are perceived as reflecting disdain for the worth or potential of most underclassmen, and as part of a system intended to drive most students away, rather than offering realistic and useful feedback.
- (iv) Harsh, competitive grading systems preclude, or discourage, collaborative learning strategies, which many students view as critical to a good understanding of the material, and a deeper appreciation of its meanings and applications.
- (v) The fairly common experience of conceptual difficulty at particular points in particular classes, which might not constitute an insuperable barrier to progress if addressed in a timely way, may, instead, begin a downward spiral of falling confidence, reduced class attendance, falling grades, and despair, leading to exit from the major.
- (vi) Teaching assistants (whether American or foreign) bear a disproportionate responsibility for the teaching of fundamental material in basic SME classes, which are overenrolled, given the pedagogical resources available.
- (vii) Overpacked curricula which lengthen the time it takes to complete an SME degree, place extra financial burdens on the growing proportion of students who must pay for their education, either by part-time employment, or by the accumulation of debt. Seniors express the suspicion that most of the overpacking of the syllabi in basic classes is maintained for "weed-out," rather than for sound pedagogical purposes.
- (viii) Curriculum overload (combined with the growing length and costs of SME majors), supports the perception that the rewards (whether material or personal) of SME-based careers following graduation are not worth the effort and costs required to get them.

We also found sufficient evidence to call into question the theory that switchers can be distinguished from nonswitchers by their inability to cope with the intrinsic "hardness" of SME majors, or their unwillingness to commit themselves to

sufficient hard work. First, we found a strong similarity between the proportions of switchers and nonswitchers who reported they had experienced conceptual difficulties in one or more SME subject(s) (i.e., 26.8% of switchers overall and 25.0% of nonswitchers). As a factor in decisions to leave SME majors, conceptual difficulties were reported by a comparatively small proportion of switchers (12.6%). Non-switchers did not suffer less than switchers from the consequences of high school preparation in mathematics or science that they subsequently found to be inadequate for college-level work; 40.4% of switchers overall, and 37.5% of nonswitchers, reported that they had been inadequately prepared by their high schools. This deficiency was clearly an important basic problem for many students, despite their apparent level of competence indicated by incoming mathematics SAT scores of 650 or more. However, conceptual difficulty was thought less important (14.8%) than ten other concerns as a final consideration in switching decisions.

One-quarter (24.0%) of switchers also described difficulty in getting help from faculty and/or teaching assistants as having contributed to their decision to leave. However, 75.4% of all switchers, and 52.0% of nonswitchers also described this problem. More switchers overall (16.9%) than nonswitchers (7.2%) reported they had not worked with peer study groups as a means to gain a better grasp of material which they found difficult. With hindsight, 11.5% of switchers considered this omission to have contributed to their leaving.

Though we did encounter switchers who were unwilling to undertake the heavy work demands and fierce pace in introductory SME classes, we also found indications that most switchers worked hard, and had struggled to persevere during their time as SME majors. The findings from a number of large-scale studies¹ have documented the higher demonstrated ability of freshmen entering SME, compared with those entering non-SME, majors. To these, we would add our finding that the mean of grade point averages (GPAs) reported by switchers just prior to their leaving SME majors was, at 3.0 (range: 1.9–3.85), not dramatically lower, than the mean of current GPAs (3.15; range: 2.95–3.95) reported by nonswitching seniors. This finding, based on the self-reported scores of our informants closely follows that of a recent (1992) study of switchers and persisters at the College of Engineering, the University of California at Berkeley.² Humphreys and Freeland's study, which examined all first-time freshmen entering the College of Engineering in the fall semesters of 1985, 1986, and 1987, found that, "students who persisted and students who switched earned comparable grade point averages (3.10 as compared with 3.07)," (p. 5). This difference was not found to be statistically significant.

We were also impressed by the length of time switchers stayed in their original majors before finally deciding to leave. The average time period spent in the major before leaving was, for engineering switchers, 2.6 years (range: 1–4 years), and for science and mathematics switchers, 2.1 years (range: 1–3 years). This finding underscores our observation from the text data that, for most students, the decision to switch was not taken until they had already expended a considerable amount of time, money, and effort in persistence.

Both the accounts of switchers, and those of nonswitchers who describe the experiences of roommates and friends, offer powerful testimony of the desire to persist, and of the efforts made to do so. We found many switchers whose level of ability and application should have been sufficient, given a more encouraging learning environment, for them to com-

plete their major. We also encountered a smaller number of multitasking switchers, the loss of whose high abilities from science-based fields may be of particular concern.³ Both switchers and nonswitchers saw their SME majors as prone to lose students who had both sufficient ability and intrinsic interest to complete the degree. In their explanations for this “wastage,” students stressed the counterproductive consequences of their faculty’s pedagogical focus on weeding out, rather than support and encouragement. Weed-out classes also had the unintended effect of driving away some of the more talented students because they lacked sufficient intellectual stimulation to sustain the students’ interest.

As we extended our inquiries to include a wider array of institutions and regions, we found more, rather than less, evidence of wastage from SME undergraduate majors. Institutional similarities in the proportion (40 to 60 percent) of SME losses, regardless of differences in institutional prestige, criteria for student entry, and the quality of incoming SME freshmen, also lend support to the hypothesis that attrition has become structural, even functional, in character. Our findings point also to the latent dysfunctions of traditional practices and policies in contributing to the loss of many well-qualified students, including some with special talents who would prefer to remain were the level of intellectual stimulation greater.

The system is even more counterproductive for students of color, and women of all ethnicities, who continue to be lost from undergraduate science in disproportionately large numbers, despite more than ten years of efforts aimed at reversing this trend. The reasons for this are more complex than we had hitherto supposed. They include the problem that female and minority freshmen, no matter how well prepared they may be, are likely to enter basic SME classes with some uncertainty about whether they “belong.” Their confidence level is neither strong, nor internalized, and is often tied to particular high school teachers who encouraged them. By contrast, faculty who teach introductory classes present themselves as wishing to discourage the kind of personal contact and support which was an important part of high school learning. Students pick up this message in faculty’s reluctance to answer questions, their brusque manner in response to “trivial” inquiries, their refusal to offer words of praise or encouragement, and in their reluctance to discuss academic difficulties in a personal manner. Many young white males recognize this behavior as part of a moral (rather than an academic) challenge which they have already encountered among adult males in other contexts—fathers, sports coaches, cadet corps officers, etc. However, the point of such challenges is totally lost on those for whom it has no cultural meaning, and for whom it runs counter to all prior learning experiences—notably, women, and students from other cultural traditions. Failing to evoke from teachers some reassurance that they are performing acceptably, and that their choice of science is appropriate, has a disproportionately negative effect on both women and students of color:

“They don’t do anything to encourage you. That’s frustrating. Maybe they’re testing you to see how committed you are to what you’re gonna do. But, it really doesn’t make any sense to me.” (Female white physics nonswitcher)

“They try to scare you. Maybe they think that’s how reverse psychology works, and that it will make you work harder. But, you’re too fragile; there’s already too much pressure from mom and dad. I don’t do my best in harsh

environments: I can push myself. I don’t need stern teachers beating up on me.” (Female white engineering non-switcher)

“It seemed a lot of people were so discouraged after that class that they left. I got a C– and kept going for a while. I ended up getting mostly B’s and A’s in my other math classes. I think they could figure out a different way. It discourages a lot of people who could still go on. I think a lot of those people have the ability, but they just feel so bad about themselves.” (Female white engineering switcher)

“Their attitude is that they don’t expect you to make it through. It’s very discouraging. You know they don’t encourage you to do your best. I felt they were telling me, ‘No, you can’t do it. You’re not going to make it.’ ” (Female mathematics nonswitcher)

It is not, we have found, accidental, that women so consistently choose the word “discouragement” to describe their reaction to faculty resistance to attempts to engage in a personal pedagogical dialogue. Young women who are looking for “encouragement” to bolster their self-confidence, but who cannot evoke it from faculty tend to feel “discouraged,” even though faculty may have said nothing overtly negative. There is no neutral ground: failure to encourage is taken as discouragement. Thus, one unintended consequence of a system with the benign intent to discover “the best” students is that high ability women leave, in the mistaken belief that they are not good enough, alongside those students of lower ability or interest level whom faculty intended to “weed out.”

The contribution of an unsupportive culture to the wastage of good students is not, however, confined to women or students of color. Failure to find adequate advice, counselling, or tutorial help contributed to one quarter (24.0%) of all switching decisions, was mentioned as a source of frustration by three-quarters (75.4%) of all switchers, and was raised as an issue by half (52.0%) of all nonswitchers, for whom it was the second most commonly cited concern. What students wanted was:

- (i) Advice on academic and career alternatives and how best to pursue them.
- (ii) Accurate information on required courses, and appropriate sequencing, in order to fulfill particular degree requirements.
- (iii) Help in understanding particular class and laboratory materials, and their application.
- (iv) Practical help or advice with problems that impinge on academic performance—especially, financial, employment, time conflicts, health, and personal matters.
- (v) Someone to take a personal interest in their progress, problems, and overall career direction.

The advising and counseling which students actually got were described as, confusing, overlapping, unreliable, inadequate, and impersonal. By far the most common words used by freshman to describe their personal encounters with SME faculty were: “unapproachable,” “cold,” “unavailable,” “aloof,” “indifferent,” and “intimidating.” A painful experience with a faculty member at an academic crisis point was often the “last straw” incident in the process leading to switching. Some nonswitchers described how close they had come to switching following a discouraging encounter with their faculty advisor:

"I left his office crying because I had asked him for help...I wanted him to take the time to explain it. And he just got irate, saying, 'Well, how many hours did you put into this? You'd better reconsider what you're doing in college.' He really put me down. I left thinking, 'Well, I'm not going to listen to that, because I know the reason I'm not doing well in his class *isn't* that I'm not smart enough.'" (Female white science nonswitcher)

"I didn't do very well the semester before, and I went to him for advice, and he basically told me that I should go ahead and switch my career field because I'd never make it...I was only a sophomore at the time, and that, like, broke my heart...I didn't know what I was going to do, but my mother said, 'Don't let anybody tell you what is going to happen in your life. You're the only one who can decide what you are going to be.'" (Female black science nonswitcher)

"I did badly in a 300-level linear algebra course, largely, I think, because of the way that he taught it. And he wrote on my paper, 'You should consider dropping this course.' Nothing else. No encouragement. No help. It's this, 'If you don't have it, get outa here,' kind of attitude." (Male white science nonswitcher)

Some who had survived described how a lucky, last-chance encounter with a faculty member who took the time to listen and give support had encouraged them to hang in just long enough to surmount their immediate problems, and to persist. The touch-and-go nature of such encounters highlights the thin line which is all that often distinguishes switchers from survivors.

Although deans and faculty sometimes ask why students do not make better use of whatever support systems are available to them, there are a number of reasons why students may find this hard to do. Some are intimidated by the unapproachable persona faculty customarily project toward underclassmen; some fear humiliation if they ask what faculty may consider to be "dumb questions;" and students who are working may not be able to attend scheduled office hours without taking time off from work. In addition, most freshmen quickly pick up the message that faculty consider it inappropriate to approach them—as opposed to teaching assistants or tutors—for help with most academic problems.

Students also told us what had been helpful to their survival. This included regular personal contact with a faculty advisor who took an interest in them; departmental systems in which students were required to meet with their faculty advisors on a regular basis (not only at times of crises); small group learning for discussion and consolidation of class material; departmental gatherings where faculty and students of different years meet and discuss topics which enhance appreciation of their discipline. They also wanted up-to-date information and advice about career options, graduate schools, and scholarships, and contact with professionals in the field who could talk about their work. Above all, they appreciated faculty, professional advisors, departmental assistants, and teaching assistants who showed an active long-term interest in their learning, their problems and their progress.

It is sometimes proposed that some of these needs are best met by a system of mentoring, and, indeed, those seniors who had developed an ongoing personal relationship with faculty, or professionals in the discipline, valued it greatly. However students have a fairly predictable, cyclical array of support needs which lie beyond the scope of most mentoring relationships. Many of their problems with the advising arrangements made by their department, college, or campus, arise because these provisions lack the coherence of "a system." It is very difficult for students to discover whom they may appropriately approach for help of different kinds. Having some structured, regular contact over time with someone—whether faculty, a peer counselor, a program officer—who listens, encourages, and gives direction to other resources, is what can make an otherwise incoherent battery of services work for students.

The issue of the "unsupportive culture" of science is just one of several interlocking processes which contribute to the loss of able students. As indicated earlier, attention to pedagogy (rather more than curriculum), and to methods of student assessment, appear to be most urgently required. In our final report, we have sought to tease out, and explain the interaction of, those aspects of the structure and culture of academic science which perpetuate high loss rates in the first two undergraduate years. We also offer some retention strategies which are grounded in the experience and suggestions of the switchers and persists themselves: Elaine Seymour and Nancy M. Hewitt, "Talking About Leaving: Factors Contributing to High Attrition Rates among Science, Mathematics, and Engineering Undergraduate Majors," Final Report to the Alfred P. Sloan Foundation on an Ethnographic Inquiry at Seven Institutions, April, 1994. It is available from the authors, at the Bureau of Sociological Research, The University of Colorado, Campus Box 580, Boulder, CO, 80309 (\$25.00 is requested to cover the cost of publication); or call (303) 492-0085. It will be available as a book, from Westview Press, Boulder, Colorado, in Spring 1995.

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¹Kenneth C. Green, "A Profile of Undergraduates in the Sciences," *Am. Sci.* **78**, 475–480 (1989); "Keynote Address: 'A Profile of Undergraduates in the Sciences,'" in *An Exploration of the Nature and Quality of Undergraduate Education in Science, Mathematics, and Engineering*, National Advisory Group, Sigma XI, the Scientific Research Society (Report of the Wingspread Conference, Racine, WI, 1989); *The State of Academic Science and Engineering*, Directorate for Science, Technology and International Affairs (National Science Foundation, Washington, D.C., 1990); P. E. White, *Women and Minorities in Science and Engineering: An Update* (National Science Foundation, Washington, D.C., 1992).

²Sheila M. Humphreys and Robert Freeland, *Retention in Engineering: A Study of Freshman Cohorts* (University of California at Berkeley, College of Engineering, Berkeley, California, 1992).

³These observations are consistent with those of Sheila Tobias in her 1990 report, *They're Not Dumb, They're Different* (Research Corporation, Tucson, AZ, 1990), and in a number of articles arising from her work.